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From Container Terminal to Smart Ports: A State of Art

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ABSTRACT

Nowadays, the Economy relies on terminals and ports, hence 80% of trade is carried out by sea. The Smart Port aims to put technology at the service of the port, to enhance the efficiency and safety of data and goods during portal operations. Smart ports answer economic challenges by adapting infrastructures and services to accommodate as many ships as possible. Transport, handling, storage, and support activities can be enhanced with new technological solutions.
In this manuscript, we will see a state of art on building Smart ports from container terminals, based on specific technologies applied to some famous smart ports. This paper is a review study on smart ports, referring to recent studies and projects, to look for chances, strengths, and weakness points, for possible future projects.

1. Introduction.

In the international context, due to the huge amount of data, methods, information users, and complex situations to solve, there is a great tendency to transform our daily life to be smarter, and this is applied in various fields and sectors of activity: Economy, Education, Energy, transport, industry, including maritime industry.

The maritime industry is the basis on which most of the global economy depends. According to the United Nations Conference on Trade and Development (UNCTAD), it reached 10.7 billion tons in 2017, which is an increase of 411 million tons [1], In 2018 [2] Global container port traffic attained 793 million TEUs (20-foot equivalent unit)volumes expanded at 2.7 percent with 11 billion tons.

During maritime industry history, great progress was experienced in various activities and services thanks to developing supply chain management. The supply chain results from an exponential development of the logistics sector, and the need to manage uncertain and dynamic distributed environments. Furthermore, this advancement is quickened with the incorporation of new advances, similar to the Internet of Things, Artificial Intelligence, Data Science, Blockchain, and other technologies. Subsequently, every one of these elements prompted the presence of the concept of Smart logistics [3].

In this paper, we will summarize how smart ports are built and their importance for the maritime industry and the global economy. In the second part, we will focus on the background of the maritime industry, we will give an overview of the container terminals concept, then we will present the terminal actors and the terminal information systems involved taking the example of Casa Port. In the third part, we move to the description of the process: the smart port notion, and some port's performance indicators, we will present the most important smart port projects, and some technologies integrated into smart ports; Finally, the last part concludes this paper with some indications for integrating technologies in smart ports, advantages and drawbacks.

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2. Container terminals.

Due to the lack of information concerning the maritime domain, this research is built on an interview with some specialists in Casa Port, to understand the Moroccan maritime context and especially the Moroccan procedure for establishing a smart port or precisely the operations and projects related to it.

2.1. Container terminals.

A container terminal is a port infrastructure specialized in the loading and unloading of containers, transported by ships specifically container ships, It is characterized by a large draft, a quay for mooring, gantries or cranes for loading and unloading containers; transport networks; and an area devoted to stacking containers;[4]

Stacking containers in the port territory is divided into three types of cargo:

a. Conventional: concerns various goods that are non - containerized (non-containerized general cargo) transported in bags, boxes, and on pallets, as well as heavy and unpackaged packages. These goods are stored in stores or considered as full-ground storage.

b. Solid bulk: concerns all products that are handled, stored, or transported without packaging such as sand, and butter. These products are unloaded directly from ships.

c. Liquid bulk: liquid product with no packaging, like oil, petroleum... It is transported directly to tank trucks and gets permission to a direct exit.

2.2. The terminal stakeholders.

Many actors interact within each other in the maritime industry, for example, port authority: The harbor master's office, and The National Ports Agency (ANP) , the ship-owners (the partner who owns the ship and takes responsibility for delivering goods or containers to the port terminal), carriers, maritime operators, shipping companies, the end customers, etc...

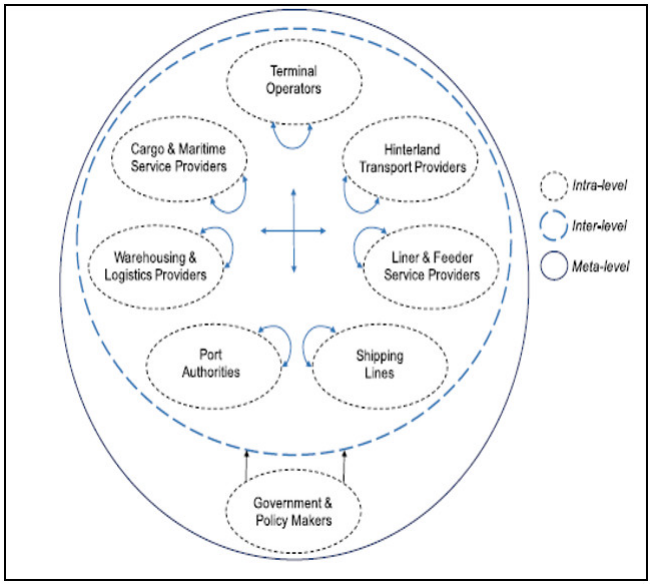
- Port authority: In the Moroccan case, the port authority is represented by the National Port Agency (ANP) which takes the responsibility for managing shipments and products in the best circumstances concerning management, expenses, time constraints, safety, equipment investments, and the growth of working capacity. It has control of the use of new Technologies of Information and Communication. This agency aims to enhance the competitiveness of the Moroccan port sector. The most important operations within stakeholders and port operators are done through the ANP with the portal PORTNET platform [5].

- Ship owners: A ship owner is an entity (a company or a person) that owns a merchant vessel (commercial ship) and is involved in the shipping industry. It equips and exploits a ship, usually for delivering cargo at a certain freight rate, calculated as either per freight or per day. Ship owners hire a certified crew and captain rather than take charge of the vessel in person [6].

- Carriers or hinterland transport providers: a person or company that transports goods or people for any person or company and is responsible for any possible loss of goods during transportation.

- Maritime operators: the maritime operators implies anyone or entity who enters into a contract with a shipper or a passenger to convey goods or people by water on their behalf.

Figure 1: Different stakeholders interacting in the port hinterland.



Source: Authors.

- Supply chain stakeholders: All entities that have an interest in a business, either affect or are affected by it. Stakeholders in the supply chain Include internal and external actors.

- Shipping companies or shipping lines: It is a business that transports cargo aboard ships. It includes Bulk cargo (transporting goods in large quantities), General cargo,(goods that must be loaded individually to different ports), oil and passenger cargo (the business of transporting people abroad a shipping line), and Special cargo (a term used for one specific product being shipped to a specific port) [7].

- Warehousing and logistics providers: It involves packing and delivering the order as well as providing storage for finished items. Both the company and the consumers may economically gain from efficient warehousing.

All these actors interact on three levels: intra-level, inter-level, and meta-level, creating an intermodal system of flow within the port territory and contributing to establishing a strong supply chain management system in the port, it's a significant factor for building a smart port.

2.3. Information Systems involved in Casa Blanca terminal.

According to [9] "Information systems have become indispensable to the competitiveness of ports, facilitating communication and decision making for enhancing the visibility, efficiency, reliability, and security in port operations under various conditions".

In the Moroccan context, ports are managed with the same information system connected to the Port-net platform; this platform is directed by an authority office the ANP (National Port Agency).

The National Ports Agency is a "Public Establishment with legal personality and financial autonomy". The Agency's technical supervision is provided by the Ministry of Equipment and Transport [10]. The Agency exercises its powers over all the Kingdom's ports except the port of Tangier Mediterranean (33 ports) [10].

Created in 2012 by the ANP (the national port agency), the limited company PORTNET is in charge of the project to set up a National Single Window to facilitate all port and trade procedures [11]. Currently, Portnet has crossed the 50,000-user mark, including over 45,000 importers and exporters, 1,500 freight forwarders, 20 banks, and over 43 administrations [11].

PORTNET also allows the exchange of data at the regional level through interoperability with the one-stop shops of other countries, thus allowing a simplification and an end-to-end integration of the logistics and commercial chains between the supplier and his customer [11]. Thus, sharing information between the various stakeholders in the port is done through the PORTNET Platform.

The relationship between the banks and the various operators of the CASA PORT is nonexistent since the financial flow is not included in the exchanges of the supply chain crossing the port.

The customs information system is BADR, The BADR system (Automated Network Customs Base) is the new online customs clearance system for goods in Morocco, both for import and export operations. It takes care of all customs procedures while integrating new concepts such as anticipation and interactivity with the port operator [12].

For each port operator, an information system is developed separately and installed to manage and facilitate its information processing.

3. Smart Ports and port performance.

In recent years, there has been an increase in maritime trade, due to the rapid expansion of e-commerce, building larger ships equipped with expanded container terminals, and the establishment of liner shipping alliances.

3.1. Smart Port Notion.

Any transformation of cities to become smart cities has involved the integration of several factors, sciences, and fields of study; it involves the appearance of the concept of intelligence in different areas of the city: smart education, smart transport, smart industry, smart logistics, etc. Therefore, it is necessary to define the concept of "Smart" before starting the rest of this article.

"Smart means: no waste of space, time, money, and natural resources. These elements depend on the current challenges of ports: spatial constraints, pressure on productivity, fiscal limitations, and the need to be green. Technology and innovations can help, but being smart is also a mindset" [13].

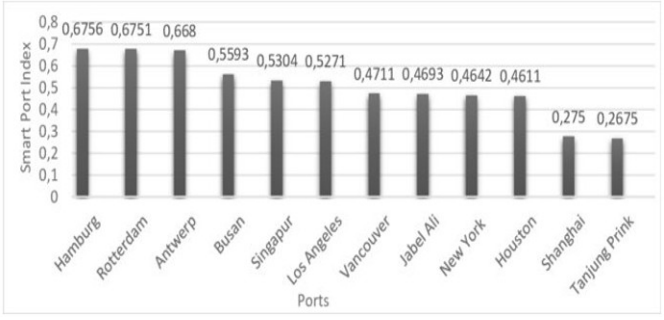
In the context of globalization and the liberalization of international trade, the number of players raised in port terminals, of different organizations, institutes, and companies interacting in the different functions of the terminal. In addition, the increase in containerization according to the report by [14], it is expected that the increase will continue in the coming years.[3] The port is the center of interest in the maritime supply chain; it establishes the connectivity of nations and the development of international trade. It integrates the modes of transport and connects producers to consumers in different markets. [3]

Smartness is being able to manage many data sources and promote sustainable activities. Effective use of technology speeds up information communication, product movement, and storage, providing the port community with the best efficiency [15].

The economy may be considered "smart" when it can provide a person with the ideal information at the ideal time to enable him to take the ideal decision, carry out the ideal course of action, and, in an ideal world, adopt the ideal strategy to change his environment in a way that will increase opportunities while minimizing risks and threats [16], [17].

According to [18], there are two different perspectives for this implementation: the first insists that the intelligence of the port is based on the ideology behind, not only the amount of integrated technology and the infrastructure of the port, that is to say: the smart use of resources and policy decisions are more important than the implementation of technologies.

Figure 2: Comparison of the Smart Port index between different ports.



Source: Salinas, 2021.

The second perspective is based on the use of recent technologies to improve the performance of the port. (port technology 2016) [18].

By [19] "A smart port may be defined as a fully automated port where all devices are connected via the so-called IOT Smart Port. A network of smart sensors and actuators, wireless devices, and data centers make up the key infrastructure of the smart port, which allows the port authorities to provide essen-

tial services in a faster and more efficient manner. The major drivers in smart ports are productivity and efficiency gains."

3.2. Port Performance.

Port performance indicators are straightforward measurements of various aspects of port operation. To serve their purpose, such indicators should be easy to compute and interpret. They should provide port management with insight into the performance of key areas [20].

In [18], authors made a smart port platform, based on quantitative metrics: SPI (Smart port index) calculated using indicators gathered from literature; these indicators are divided into four domains: operations, environments, energy, safety, and security. This method is based on analyzing use cases from 16 ports.

The Performance of the port is measured based on some criteria: the degree of interlinking the information and the communication system, more efficient traffic management, control and ability to plan proactively, the amount of TEU (Twenty-foot equivalent unit) throughput per year, turnaround time, time spent in the truck (driver), the distance calculated in kilometers driven by the truck, the stay rate of ships in their berths.

In the Moroccan context, the performance of the port depends on some factors:

Duration of treatment of the ship: the global time spent on all operations from its berth to its departure.

TEU: equivalent to twenty feet (the smallest container) it's the unit to calculate the amount of product trade.

The port draft: defines the smallest depth of water through which a ship or boat may safely sail. It means the capacity of a port to serve ships in number, but more important the type of ships and vessels served.

3.3. Smart port projects.

Several smart port projects have been created in recent years, in each case different criteria were applied, for different port functions and operations. In these smart ports, the notion of Industry 4.0 with the digitalization process remain a necessity to transform gradually a port terminal to a smart port. In this direction, the implementation of the newest technologies is only a step, on the transformation process to intelligent ports.

In the next table, we present the most important ports that became Smart Ports, with their functions and their capacities, mentioning technologies integrated into these ports and terminals and port operations and services where they are used.

The port of Singapore is a global port terminal that is specialized in transshipment and crude oil. In this port technology is based on IOT platforms to maintain cyber-physical security, as well as the technical aspects of a new port transport system.

In The port of Rotterdam, the capacity is More than 140,000 ships are handled annually, policy in this port consists of implementing the digital Twin technology that provides information about the degree of interaction of different pieces of equipment. Moreover, Digital transformation is expanded to IBM and Cisco, and IOT system with Iot sensors are installed to provide a path for autonomous shipping and logistics, as well as improving g data processing and network intelligence. IoT sensors, in other hand, monitor the pressure, turbidity, and water flow.

Concerning the port of Hamburg, it is an automated port that receives more than 8,000 ships call annually, more than 200 cargo trains arrive and quit daily. In the port of Hamburg, a group of technology is integrated, for example: the 5G-enabled IOT. The SAP HABA cloud platform, Augmented Reality, and Augmented Reality glasses, and finally, Sensors which are fixed on the resident shipping fleet.

Table 1: Most important ports with their activities and technologies implemented.

Ports	Country	Port function	Capacity	Technologies	Disruptive changements
Port of Singapore	Singapore	Global maritime capital for transshipment and crude oil	Will be increased by 21 million TEUs by 2027, to 65 million TEUs by 2040	IOT	Develop cyber-physical security and smart port operations, as well as the technical aspects of a new port transport system.
Port of Rotterdam	Netherlands		More than 140,000 ships are handled annually	- Digital Twin Digital transformation is expanded to IBM and Cisco; to incorporate the Watson IOT system and the Kinetic IOT platform - IoT sensors	Information on how the various pieces of equipment interact with one another. Enhancing data processing and network intelligence, and to provide a roadmap to autonomous shipping and logistics. IoT sensors monitor water flow, turbidity, and pressure.
Port of Hamburg	Germany	Port automation	More than 8,000 ships call annually, --more than 200 cargo trains arrive or depart daily	- 5G-enabled IOT - The SAP HABA cloud platform - Augmented reality - Using Augmented Reality glasses. - Sensors fixed on the resident shipping fleet	Remote control of traffic lights and shipping) To operate remotely Cellular-enabled traffic (more responsive to traffic flows) Real-time location movement and environmental data

Source: Authors.

3.4. Technologies integrated in smart ports.

According to [21]," A smart port is an automated port that uses new technologies such as big data, Internet of Things (IOT), Blockchain solutions and other smart technology based methods to improve performance and economic competitiveness. With these technologies, smart ports can also improve environmental sustainability. In an ideal smart port, processes would be automated and connected via IOT."

In the Hamburg port, It has processed containers automatically through its docks for quite a long time. More recently, it has engaged IOT technologies to make smarter use of its urban setting, which has bounded its expansion.

As confirmed by [19], Various sensors such as inertial sensors, ultrasonic sensors, eddy current sensors, radar, lidar(laser detection and ranging), imaging sensors, and RFID readers and

tags are used to collect required data in order to transform the "port" into a "smart port".

4. Related Works.

By [41], the authors aim to provide an overview of existing publications on environmental protection in smart cities, this paper focuses on structuring the research field into a research process to gain a more systematic view of the application of Green IS, with more than 1500 articles of detailed literature.

The success of the supply chain stands on building trust among stakeholders, [22] proposes an experimental study where they conduct a designing and developing software connector module that connects an Ethereum-like Blockchain to a general business information system. for companies to send data to the Blockchain and check the data authenticity.

In [23], authors used service science to re-conceptualize a supply chain port to a Smart port by using a case study approach in the port of Salerno in Italy, by implementing a logistic framework.

Authors in [24] propose some practices and initiatives for transforming the Croatian port to a smart port while specifying digital integration that makes the seaport smart.

According to [25], the establishment of a smart port in China requires multiple fields, industries, and benefits, authors suggest key points for the construction of future smart ports from the perspective of Internet of Things (IoT) information platform, logistics supply chain integration and supply chain financial information platform construction, by integrating Big data, Internet of things, and artificial intelligence.

In [26], authors propose a systemic framework for evaluating the benefits of microgrids, focusing on demonstrating how a set of smart port index (SPI) metrics integrated into the microgrid planning process can improve the smartness of the port. This framework, according to writers, is capable of improving port operations' productivity, sustainability, and reliability.

According to [27], authors used input-output analysis combined with Delphi surveys to estimate the economic impact of the intelligent port industry on the economy in Korea with sophisticated parameters.

Conclusions.

Integration of technologies in the process of transforming seaports to smart ports should take charge of some points:

- Information systems included in the port have great importance either in port performance [28] or in data integration and compatibility, which infects the different technologies used with the information system. The integrity of the technology within the terminal operating system is crucial to judge its success.

- The large amount of information circulating to and from the ports requires sophisticated data management and sufficient storage space with the fluidity of sending and receiving between the different ports. That said, the scalability of the system and the technologies adopted is important.

- During the Covid 19, one of the most noticed problems is the great impact of intermediaries on the delay of operations and delivery of products of all kinds, so the integration of technology capable of overcoming this problem is an important change for smart ports.

One of the technologies proposed to overcome intermediaries is Blockchain technology. The integration of this technology has already been achieved despite its few drawbacks. Blockchain has proved its efficiency concerning transparency of transactions, immutability of data, trustless scalable and interoperable network.

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